Tracking the Moon—In Simple English

Practical Ideas for Designing and Aligning a Polar Mount

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A MAJOR pitfall facing the prospective moonbouncer is the antenna mount and tracking system. Even a 50-foot dish is of no value in lunar communication, if it cannot be pointed at the moon and kept there. When we began our moonbounce efforts, many hours were spent pouring over astronomy texts. It was determined rather quickly that a whole new language would have to be learned for a proper understanding of the moon-tracking problem. Gathered together here are some of the essentials involved.

Earth-Space Relationship

Understanding the earth-moon relationship in space is the first step in solving the moon-tracking problem. This relationship is best illustrated with a polar mount, as in Fig. 1. A polar mount is simply an elevation-azimuth mount with its azimuth axis parallel to the axis of the earth. Thus a polar mount at the equator would have its axis parallel to the earth (horizontal, to the viewer on the ground), while at the North Pole the axis would be vertical, or at a 90-degree angle to the plane of the earth. Your latitude determines the position of the polar axis with respect to the earth's surface, as illustrated in Fig. 1. Once this is determined, we can proceed to a few other terms.

Celestial Equator. An extension of the earth's equator; the circle that would be formed at a right angle around the polar axis.

Meridian. The north-south line directly overhead.

Hour Angle. The angle in degrees to the right of the meridian. (Degrees can also be transferred into time: 15 degrees equals 1 hour; 1 degree equals 4 minutes.)

Declination. Angle in degrees north or south of the celestial equator.

Using the Nautical Almanac

This is the most important tool you will use in setting up, calibrating, and using your moonbounce antenna. It is available from the U. S. Government Printing Office for $2.00. Be sure you get the right book; there is a similar publication from the same source titled *The American Ephemeris and Empirical Nautical Almanac.* This is more expensive, and harder to use for amateur applications.

On page 39 is a portion of the tables found in the *Nautical Almanac.* It will be noted that the position of the moon is plotted for each hour of GMT. As an example, at 1200 GMT Jan. 1, 1965, the GHA (Greenwich Hour Angle) is 15 degrees 16.5 minutes. This means that the moon has passed overhead at Greenwich, and is now 15 degrees 16.5 minutes, or just over one hour, to the right of the meridian, as the observer faces south. The declination is given as S 23 degrees 39.5 minutes, which means that the moon is at this position south of the celestial equator.

Once you know where the moon is at Greenwich, a simple formula may be applied to determine its position with respect to your own location. The declination is always the same, no matter where you live. The only factor that changes is the hour angle. The Local Hour Angle (LHA) can be obtained by the formula

$$\text{LHA} = \text{GHA} \begin{matrix} - \text{ west} \\ \text{longitude.} \\ + \text{ east} \end{matrix}$$

Getting back to our example, suppose you I've at 75 degrees west longitude. We find that the moon would have an LHA of 300 degrees 16.5 minutes, or approximately 4 hours before meridian.

Mount Design Considerations

After you examine your almanac you will discover a few facts about the moon's habits that will help you to design a mount. First of all, the moon spends about two weeks above the celestial equator and about two weeks below. The maximum declination is about 25 degrees

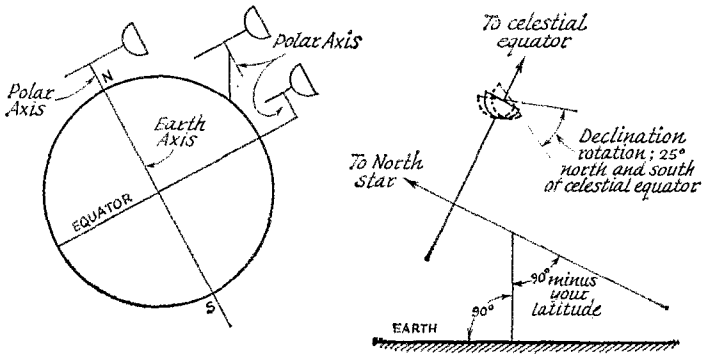

Fig. 1—Principles of the polar mount for moon tracking. At the left it can be seen that the polar axis is always parallel to the axis of the earth. Its position with respect to the earth's surface depends on the latitude of the observer. Two planes of rotation are required; the declination, which may be varied a small amount from day to day as required; and hour-angle, which should be controlled with a clock drive to follow the moon.

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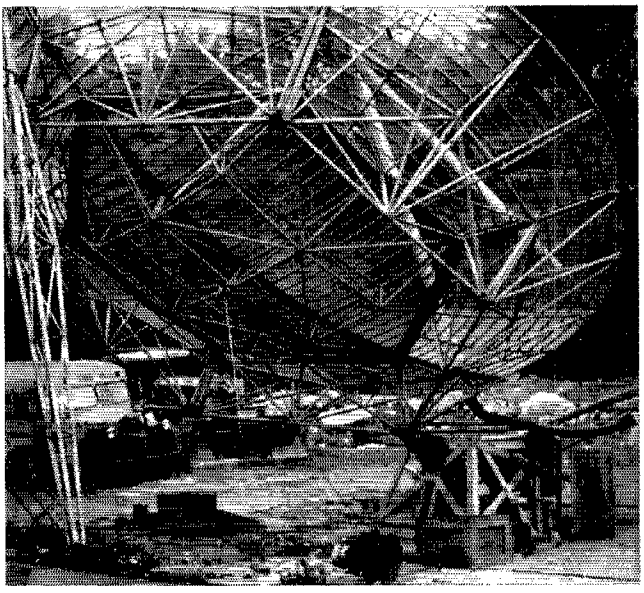

Fig. 2—Simplified polar mount and 28-foot dish at W1BU. Principles of the mount and its clock drive are explained in the text.

north or south of the celestial equator. Tracking ability for about 3 to 5 hours of hour angle each side of local meridian should be satisfactory.

At this point it is possible to make some compromises in order to simplify the mount in favor of a larger antenna. For instance, at W1BU, Sam gave up two weeks out of a lunar month in order to use the 28-foot dish of Fig. 2 in recent moonbounce tests. He can elevate the antenna above, but not below, the celestial equator. The high edge (upper left in the picture) is elevated to the desired position, while the lower edge rests on the pedestal at the lower right. The hour angle is controlled by a clock drive, just visible at the lower center. Though complex enough, this is far simpler than the true polar mounts used on the 18-foot dish at W1BU, or the mount and drive for the 256-element collinear array at W3SDZ, Fig. 3.

Calibration of the Mount

Obviously, if you are going to use the information in the *Nautical Almanac* with your mount, there must be some system of readout. There are

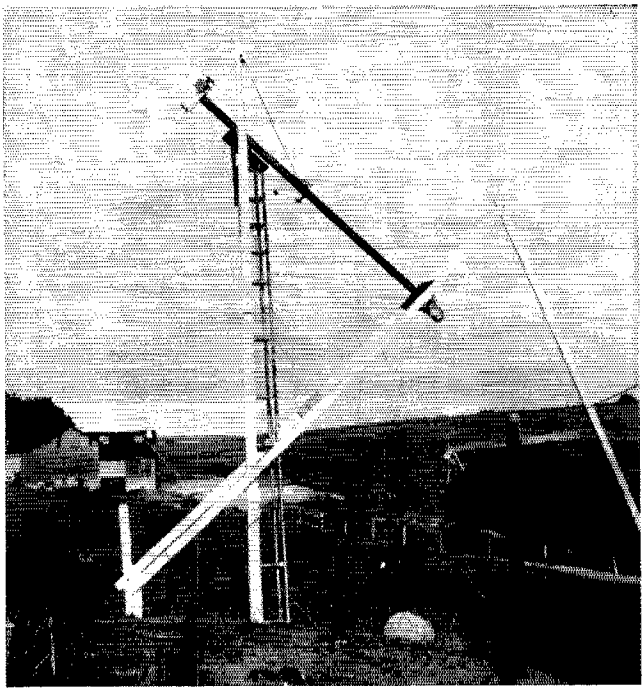

Fig. 3—Polar mount at W3SDZ, before the 256-element 432-Mc. collinear array was in place. The complete array is pictured in November 1964 QST, page 75.

many possibilities, and many different systems will evolve. As a starting point, a few ideas will be discussed here, and then "to each his own."

As a practical matter, the declination need be set no more than once per day, for it changes less than 2 degrees in 24 hours. For a few hours of moonbouncing effort each day, less than 1-degree variation is involved. Unless your antenna pattern is much sharper than the best amateur efforts to date on frequencies below 1300 Mc., this error is no problem. Declination readout can be rather simple: a calibrated scale on the antenna mount, a selsyn readout, or even a good 10-turn pot geared to the declination axis, and connected to a mercury battery and a meter. Anything accurate to plus-or-minus 1 degree should be all right.

Hour-angle readout and automatic tracking are the chief problems in moon tracking. The moon appears to move across the sky at slightly less than 15 degrees per hour. Actually, it is the earth that is moving at 15 degrees per hour. The moon is also moving, but at less than 1 degree per hour. Thus our basic problem is to drive the polar or hour-angle axis at 15 degrees per hour with a clock. The simple procedure of turning off the hour-angle drive for about 3 minutes once each hour, until the moon catches up, keeps things more than accurate enough for antenna tracking.

Now a "clock" doesn't necessarily have to look like a clock. For instance, a large synchronous 60-cycle motor driving a gear train at 1 revolution per day, coupled directly to the hour-angle axis, will work. The W1BU system is shown schematically in Fig. 4. Actual readout can be by any method that will develop plus-or-minus 1-degree accuracy.

When the mount is made, the antenna mounted, and the readout devices reading, the next question will be where is the antenna *really* pointing? This may sound simple, but most would-be moonbouncers have had trouble with this problem. Fortunately, nature has provided

G.M.T.		SUN				MOON					
		G.H.A.		Dec.		G.H.A.	v	Dec.		d	H.P.
d	h	°	′	°	′	°	′	°	′	′	′
	00	179	09·2	S23	02·3	201	09·9	11·7	S22	48·3	4·9	54·0
	01	194	08·9		02·1	215	40·6	11·7	22	53·2	4·7	54·0
	02	209	08·6		01·9	230	11·3	11·7	22	57·9	4·7	54·0
	03	224	08·3		01·7	244	42·0	11·6	23	02·6	4·5	54·0
	04	239	08·0		01·5	259	12·6	11·6	23	07·1	4·4	54·0
	05	254	07·7		01·3	273	43·2	11·5	23	11·5	4·4	54·0
	06	269	07·4	S23	01·1	288	13·7	11·6	S23	15·9	4·2	54·0
	07	284	07·1		00·9	302	44·3	11·5	23	20·1	4·1	54·0
	08	299	06·8		00·7	317	14·8	11·4	23	24·2	4·0	54·0
F	09	314	06·5		00·5	331	45·2	11·5	23	28·2	3·8	54·0
R	10	329	06·2		00·3	346	15·7	11·4	23	32·0	3·8	54·0
I	11	344	05·9	23	00·1	0	46·1	11·4	23	35·8	3·7	54·0
D	12	359	05·6	S22	59·9	15	16·5	11·3	S23	39·5	3·5	54·0
A	13	14	05·3		59·7	29	46·8	11·4	23	43·0	3·5	54·0
Y	14	29	05·0		59·5	44	17·2	11·3	23	46·5	3·3	54·0
	15	44	04·8		59·3	58	47·5	11·3	23	49·8	3·2	54·0
	16	59	04·5		59·1	73	17·8	11·2	23	53·0	3·1	54·0
	17	74	04·2		58·8	87	48·0	11·3	23	56·1	3·0	54·0
	18	89	03·9	S22	58·6	102	18·3	11·2	S23	59·1	2·9	54·0
	19	104	03·6		58·4	116	48·5	11·2	24	02·0	2·7	54·0
	20	119	03·3		58·2	131	18·7	11·2	24	04·7	2·7	54·0
	21	134	03·0		58·0	145	48·9	11·1	24	07·4	2·5	54·0
	22	149	02·7		57·8	160	19·0	11·2	24	09·9	2·5	54·0
	23	164	02·4		57·6	174	49·2	11·1	24	12·4	2·3	54·0

Table I—Section of a page from the *Nautical Almanac*, showing solar and lunar data for each hour of January 1, 1965, at Greenwich.

us an almost constant radio signal that permits a rather accurate calibration of the antenna system to be made. That signal comes from the sun. It will be seen that the almanac gives identical information on GHA and declination for the sun; thus, by listening to solar noise you can calibrate your polar mount in the same terms of reference as you will use in moon tracking. Some time spent reading K2LMG's "Antenna Patterns from the Sun," *QST* for July, 1960, will be well spent at this point.

What you have just read covers some of the essentials. It is hoped that enough information has been given to enable the prospective moonbounce enthusiast to determine his requirements for mounting and tracking. If any serious experimenter in this field needs help at this point, the author will be glad to try to be of assistance. QST

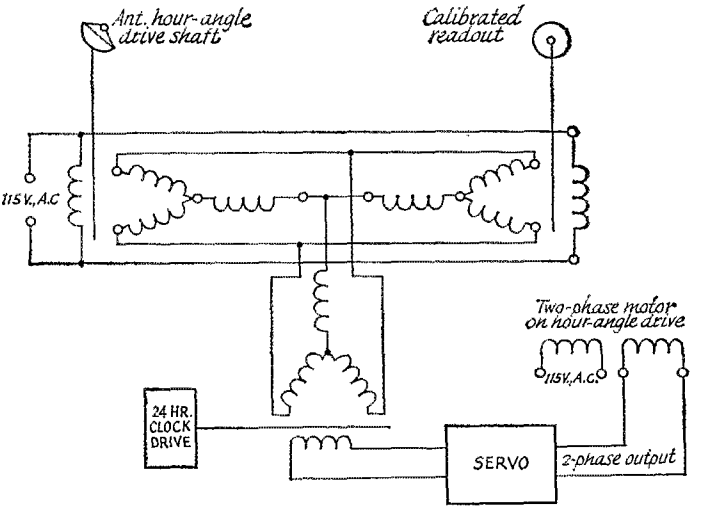

Fig. 4—Schematic diagram of the clock drive and readout system at W1BU.